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PLANT GROWTH ON A GRAVEL SOIL: GREENHOUSE STUDIES

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Two greenhouse studies were performed with gravel soils to determine the requirements for nitrogen (N), phosphorus (P), and potassium (K) for grass establishment and to assess the establishment performance of 15 types of grasses. The fertilizer study consisted of 30 treatments, each representing a different combination of application rates of N, P and K. A seed mixture containing 'Nugget' Kentucky bluegrass, 'Pennlawn' red fescue, and annual ryegrass was sown, and the plants were harvested 133 days after sowing. Plant leaf and root weights were measured, and soil samples were analyzed for pH, P, K and soluble salts. In the grass study, 15 grasses were grown for 76 days. All treatments were fertilized at the beginning of the study. Plant establishment was periodically assessed and yields were measured at the end of the study. In the fertilizer study, N and P were shown to be limiting to leaf growth on this soil.

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Applications of P were the most beneficial for root growth. Needs for K were less evident, but it was required for maximum leaf growth at the higher application rates of N and P. The greatest yields were recorded when all three elements were applied, while at the lower application rates only N and P were required to promote growth. Plant leaf growth was closely correlated with root growth. Soil pH decreased with increased rates of fertilizer. In the grass study, three tall fescue varieties and two ryegrasses established themselves more rapidly than the other grasses. Reubens Kentucky bluegrass, FL 1 hard fescue, Pennlawn red fescue, the tall fescues, and the ryegrasses were the best yielders. The fertilizer became less of a factor in plant growth after the initial two months. Grasses which had good vigor and color after 76 days were Jamestown and Pennlawn red fescue, Reubens and common Kentucky bluegrass, K-31 and T-5 tall fescue, FL 1 hard fescue, Yorktown II perennial ryegrass, annual ryegrass, and sheep fescue.

PREFACE

This report was prepared by Antonio J. Palazzo, Research Agronomist, and John M. Graham, Biological Technician, of the Earth Sciences Branch, Research Division, U.S. Army Cold Regions Research and Engineering Laboratory. The work was funded by DA Project 4A762720A896, *Environmental Quality for Construction and Operation of Military Facilities,* Task 04, *Land Use Planning,* Work Unit 003, *Revegetation of Terrain After Construction in Cold Regions.*

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PLANT GROWTH ON A GRAVEL SOIL: GREENHOUSE STUDIES

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INTRODUCTION

Proper fertilization techniques and plant selection are needed to successfully stabilize gravel soils. Seedling establishment can be enhanced by application of a 4- to 8-inch layer of fertile topsoil, but this soil can be both difficult to obtain and expensive.

Research at CRREL has shown that commercial fertilizer applications of up to 60, 26 and 50 lb/acre of nitrogen (N), phosphorus (P) and potassium (K), respectively, to a gravel soil were not sufficient to obtain satisfactory plant establishment and growth (Palazzo et al. 1978). In that study, better establishment and growth were noted for grasses receiving 40 to 80 wet tons/acre of sewage sludge as a fertility source. The sludge contained about 1.22, 0.61 and 2.47% of N, P and K, respectively.

Although little information exists on nutrient limitations in gravel soils, research has been performed on agricultural subsoils. Several studies have noted that subsoil additions of N, P, K and zinc (Zn) promote plant growth (Carlson et al. 1961, Eck et al. 1965, Eck 1968, Olson 1977).

Information is needed to determine appropriate seed mixtures for use in stabilizing gravel soils. Desirable traits of a seed mixture include rapid establishment and persistence on a long-term basis (or until native vegetation can become dominant). Inclusion of legumes in the mixture is also desirable since they can assist in increasing soil N and improve soil fertility.

The objectives of this study were 1) to determine optimum application rates of N, P and K for grass establishment on a gravel soil without applying topsoil or sewage sludge and 2) to assess the establishment rates of 15 different grasses on a gravel soil.

MATERIALS AND METHODS

Two greenhouse studies are discussed in this report. One, called the "Soil Fertility Study," concerned the application rates of N, P and K. The other, called the "Grass Study," dealt with the performance of various grasses on gravel soil.

Soil fertility study

This study consisted of 30 treatments, each representing a different combination of application rates of N, P and K (Fig. 1). There were three replications of each treatment. Nitrogen was applied at the equivalent of 0, 44, 88, 132 and 176 kg/ha; P at the equivalent of 0 and 66 kg/ha; and K at the equivalent of 0, 165 and 330 kg/ha. The sources of the nutrients were: N, ammonium nitrate (34-0-0); P, superphosphate (0-20-0); and K, muriate of potash (0-0-60). The fertilizers were mixed with the soil in 20-cm-diameter plastic pots. The chemical and physical properties of the gravel soil before fertilizing are shown in Table 1.

Table 1. Initial chemical and physical analysis of the unamended soil after removing pebbles and stones.

pH	6.9
phosphorus (kg/ha)	77
potassium (kg/ha)	77
soluble salts (mhos$\times 10^{-5}$/cm)	10
organic matter (metric tons/ha)	11.5
texture	
sand (%)	80
silt (%)	18
clay (%)	2

Figure 1. Overview of Soil Fertility Study.

The seed mixture, which included perennial grasses tolerant of low temperatures, was sown on 17 November 1977. The species and seeding rates were: Nugget Kentucky bluegrass (*Poa pratensis* L.), 0.07 g/pot; Pennlawn red fescue (*Festuca rubra* L.), 0.07 g/pot; and annual ryegrass (*Lolium perenne* L.), 0.04 g/pot. The pots were watered regularly. Plants were harvested on 29 March 1978, 133 days after sowing.

Plant leaves (all vegetation above ground) and roots (all vegetation below the surface) were harvested, washed in distilled water, and dried at 70°C for 48 hours. After drying, the tissues were weighed to determine the quantity of dry weight biomass produced per pot.

The leaf and root weight data were evaluated using the analysis of variance technique, and treatment means were compared using the Least Significant Differences Test (Little and Hills 1972).

Soils were also sampled and the replication data for each treatment were combined. Soils were analyzed for P, K, soluble salts, and pH using standard methods (Liegel and Schulte 1977).

Grass study

In this experiment, a similar gravel soil (Table 1) was collected and placed in 20-cm-diameter pots. The pots were fertilized at the rate of 2.08 g/pot with a 15-15-15 grade fertilizer, equivalent to 0.31, 0.14 and 0.26 g/pot of N, P and K, respectively.

Fifteen grasses were planted using three replications. The seeds were sown by broadcasting over the soil surface. The grasses sown were: common, Reubens, Ram and Baron Ke .tucky bluegrasses (*Poa pratensis* L.); FL 1 hard fescue (*Festuca ovina* var. *duriuscula* L.); Jamestown and Pennlawn red fescue (*Festuca rubra* L.); sheep fescue (*Festuca ovina* L.); K-31, T-5 and L-FA-Syn I tall fescue (*Festuca arundinacea* Schreb.); Nordan crested wheatgrass [*Agropyron desertorum* (Fisch. ex Link) Schult.]; Oake intermediate wheatgrass (*Agropyron intermedium* [Host] Beauv.); Yorktown II perennial ryegrass (*Lolium perenne* L.); and annual ryegrass (*Lolium multiflorum* Lam.). The seeding rates of the various grasses are shown in Table 2.

Table 2. Approximate seeding rates of grasses.

Species	Seeding rate (mg/pot)	Seeding rate (seeds/pot)
Kentucky bluegrasses		
Common	51	280
Reubens	51	280
Baron	51	280
Ram	51	280
Fescues		
FL 1 hard fescue	62	82
Jamestown red fescue	62	82
Pennlawn red fescue	62	82
Sheep fescue	62	82
Tall fescues		
K-31	62	68
T-5	62	68
L-FA-Syn I	62	68
Wheatgrasses		
Nordan crested wheatgrass	62	44
Oake intermediate wheatgrass	62	44
Ryegrasses		
Annual ryegrass	62	34
Yorktown II perennial ryegrass	62	34

The plants were allowed to grow for 76 days. During this time, pots were watered as needed. Measurements of the mean heights of the grasses were taken 11, 19, 33, 56, 68 and 76 days after seeding. After 76 days, plant tops were harvested 2 cm above the soil surface. The leaves were dried at 70°C for 48 hours and dry weights per pot were recorded. The height and leaf weight data were statistically evaluated as described in the soil fertility study methods.

RESULTS AND DISCUSSION

Soil fertility study

The leaf and root weights and soil analyses for each treatment are shown in Table 3. Plant leaf growth was responsive to the various application rates of N and P. An equivalent of 88 kg N/ha was required to obtain a significant increase in growth when only N was applied. When N was applied in combination with 66 kg P/ha, a significant increase in yields was noted at the lower 44 kg N/ha rate. This occurred in all treatments which received N and P, regardless of the amount of K. No significant increases in leaf growth ove the unfertilized control were observed when applying P alone (treatment 0-66-0) or K alone (treatments 0-0-165 or 0-0-330). The greatest aboveground yields were noted when applying all three elements at rates of 132 or 176 kg N/ha, 66 kg P/ha, and 165 or 330 kg K/ha. The combination of 88 kg N/ha, 66 kg P/ha and 330 kg K/ha also produced good aboveground yields. Differences in grass leaf growth as affected by several combinations of applied nutrients are shown in Figure 2.

The greatest root weights were found in treatments which received P (Table 3). Increases in root weights with either N or K applications were variable. Nitrogen tended to increase root weights but this response

Table 3. Leaf and root weights and soil pH, P, K and soluble salt contents for each treatment.

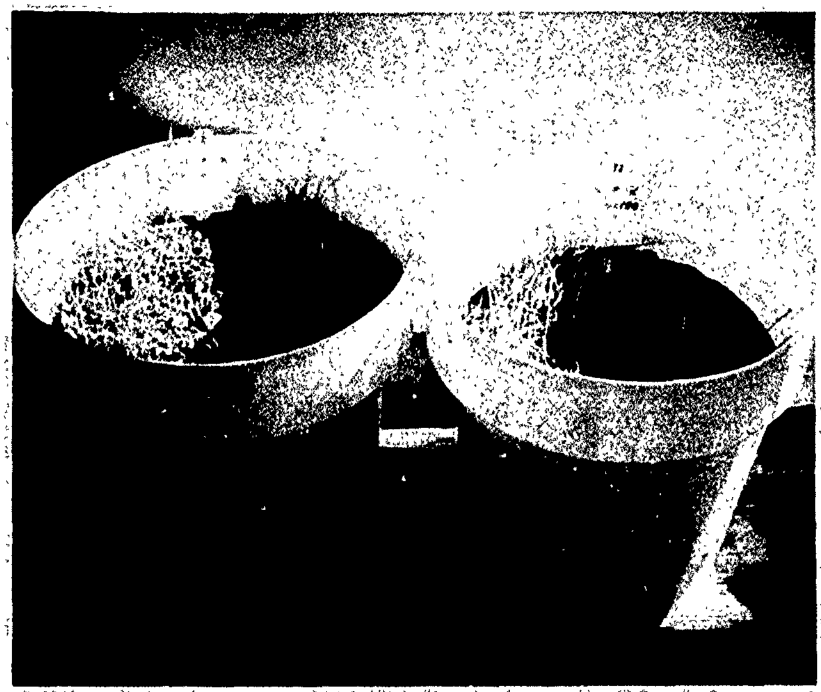
Treatment			*Plant weights*		*Soil analysis*			
N (kg/ha)	*P (kg/ha)*	*K (kg/ha)*	*Leaf (g/pot)*	*Root (g/pot)*	*pH*	*P (kg/ha)*	*K (hg/ha)*	*Soluble salts (10^{-5} mhos/cm)*
0	0	0	1.18	3.91	6.9	77	77	10
44	0	0	1.68	5.78	6.6	74	66	10
88	0	0	4.07	13.85	6.7	59	66	10
132	[illegible]	0	3.63	10.20	5.7	74	55	10
176	0	0	3.14	11.09	5.2	72	66	20
0	66	0	2.18	15.32	6.1	99	66	20
44	66	0	4.32	32.91	6.1	154	72	20
88	66	0	5.58	12.84	6.1	125	77	20
132	66	0	4.80	16.74	5.6	191	72	25
176	66	0	5.75	13.09	5.4	121	61	30
0	0	165	1.10	2.65	6.0	70	88	10
44	0	165	2.10	6.50	5.9	76	105	25
88	0	165	2.61	6.75	5.7	69	50	25
132	0	165	2.30	4.15	5.3	74	121	30
176	0	165	1.80	4.67	4.9	79	138	40
0	66	165	1.49	5.38	5.8	143	88	23
44	66	165	5.03	29.82	5.9	153	105	25
88	66	165	5.46	13.26	5.9	121	105	30
132	66	165	8.42	23.81	5.8	121	116	20
176	66	165	7.31	12.14	5.3	110	110	50
0	0	330	1.33	2.64	5.8	83	154	23
44	0	330	2.20	9.85	5.8	74	182	30
88	0	330	1.21	1.95	5.1	69	237	35
132	0	330	1.72	6.06	5.2	68	231	35
176	0	330	0.75	5.81	5.2	67	231	55
0	66	330	0.65	19.29	5.8	171	193	40
44	66	330	3.37	10.60	5.9	123	215	55
88	66	330	7.80	34.55	6.1	123	149	25
132	66	330	9.47	24.66	5.9	114	143	35
176	66	330	7.45	13.97	5.2	127	171	25
	LSD*	0.05	1.8	12.9				

* Least significant difference.

a. Treatments 0-0-0 (left) and 120-0-0 (right).

b. Treatments 0-0-0 (left) and 0-60-0 (right).

Figure 2. Grass growth as affected by various combinations of application rates of nitrogen, phosphorus and potassium 75 days after seeding.



c. Treatments 0-0-0 (left) and 0-0-150 (right).

d. Treatments 0-0-0 (left), 40-60-150 (center), and 80-60-150 (right).

Figure 2 (cont'd).

e. Treatments 0-0-0 (left), 80-60-300 (center), and 120-60-300 (right).

Figure 2 (cont'd). Grass growth as affected by various combinations of application rates of nitrogen, phosphorus and potassium 75 days after seeding.

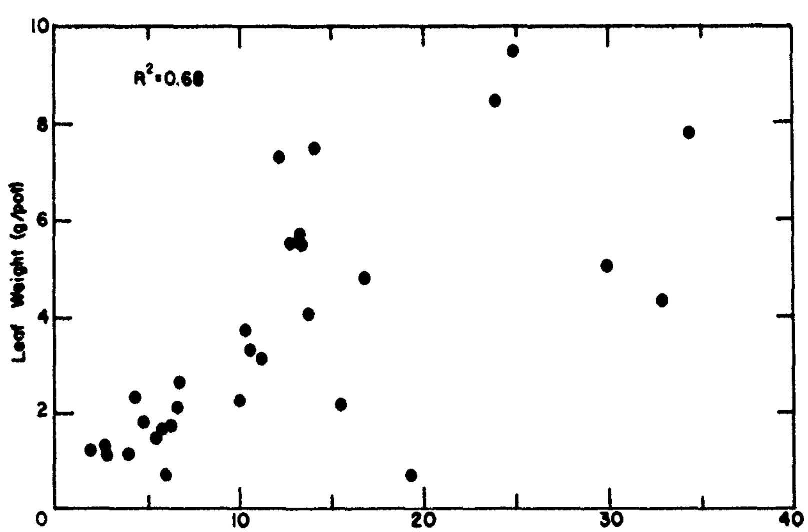


Figure 3. Correlation of leaf and root weights for the 30 treatments studied.

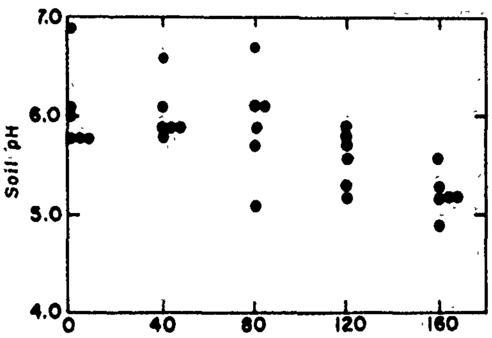


Figure 4. The effects of applied nitrogen on soil pH for all treatments after 133 days.

depended on P and K levels. Leaf and root growth were positively correlated (Fig. 3).

The soils were analyzed after 133 days and the results used to show the residual effect of the applications of commercial fertilizer and changes in soil fertility due to the various treatments.

Applications of commercial fertilizer increased soil levels of P, K, and soluble salts and decreased soil pH (Table 3 and Fig. 4). In general, increases in the various combinations of applied N, P and K increased the soluble salt content of the soil. The salt content of the soil did not reach levels considered damaging to grass growth (Table 3). Soluble salt concentrations which would reduce yields of tall fescue are reported as being 6800x 10^{-5} mhos/cm (Carter 1975).

Increases in the N fertilizer rate decreased soil pH (Fig. 4 and Table 3). This is probably due to the nitrification of ammonia N in the soil. Therefore, applications of lime may be needed to counteract any excess acidity generated by repeated fertilizer applications. The amount of lime will depend on the acidifying effect of the fertilizer (Pesek et al. 1971).

Table 4. Plant heights (cm) during study and yields (g/pot) after 76 days growth.

Grasses	*Plant height (days after seeding)* 11	19	33	56	68	76	*Plant yield*
Kentucky bluegrasses							
Reubens	1.2	2.8	4.3	9.0	9.3	9.7	2.25
Baron	1.5	2.2	3.3	5.5	4.7	5.7	1.60
Ram	0.7	1.8	3.0	4.5	4.3	5.3	1.40
Common	2.0	3.3	4.7	5.8	7.0	6.7	1.88
Fescues							
FL 1 hard fescue	3.2	4.8	6.3	9.5	8.0	8.7	3.47
Jamestown red fescue	2.0	3.3	3.7	5.8	5.8	6.0	1.57
Pennlawn red fescue	3.2	5.2	6.3	8.8	9.7	9.0	2.63
Sheep fescue	2.0	3.8	5.0	5.8	5.0	5.3	1.19
Tall fescues							
K-31	3.3	6.8	9.0	10.0	10.7	10.7	3.10
T-5	4.0	7.0	8.0	9.0	9.3	9.7	2.59
L-FA-Syn I	3.3	6.0	8.0	10.8	10.3	13.0	3.26
Wheat grasses							
Nordan crested	3.8	5.3	6.3	5.5	5.8	5.7	0.97
Oake intermediate	5.2	5.2	6.5	7.5	6.5	6.0	1.85
Ryegrasses							
Annual	5.8	6.2	10.3	13.0	12.0	12.7	3.45
Yorktown II perennial	5.0	6.8	9.0	11.3	10.0	9.7	2.53
LSD* 0.05	0.6	0.7	1.1	5.4	1.3	4.8	1.2

* Least significant difference.

Grass study

Grass height measurements taken up to 33 days of growth indicated that the tall fescues (TF) and ryegrasses established themselves faster than the other plants (Table 4). After 33 days annual ryegrass (AR) was the most aggressive species. Common and Reubens were the best of the Kentucky bluegrasses (KB), and K-31 the best of the tall fescues (TF). Jamestown and Pennlawn red fescue (RF), FL 1 hard fescue (HF), sheep fescue and Yorktown II perennial ryegrass (PR) were all doing well on this soil. Those doing poorly included Ram KB (probably due to the greenhouse disease "damping off") and Baron KB.

Color differences between plants were noted after 56 days of growth, apparently due to the loss of soil fertility. After this time growth slowed (Table 4) and a general yellowing in some grasses was noted. These grasses included Baron and Ram KB, Pennlawn and Jamestown RF, and L-FA-Syn I TF. Good green color was noted in Reubens and common KB, K-31 and T-5, TF, FL 1 HF, sheep fescue, Yorktown II PR, AR, Nordan CWG and Oake IWG.

Visual observations as to vigor were performed to determine differences in soil-covering characteristics of the plants. After 68 days there was improvement in the growth of Jamestown and Pennlawn RF. Other types which both looked good and were aggressive were Reubens and common KB, K-31 and T-5 tall fescue, FL 1 HF, Yorktown II PR, AR, and sheep fescue.

Plant yields were recorded after 76 days of growth (Table 4). Reubens was the highest yielding variety among the KBs, followed by common. FL 1 HF and Pennlawn RF were the best among the fescues, while all the tall fescues produced high yields. Annual ryegrass had a higher yield than Yorktown II PR, but both yielded well. The wheatgrasses were low yielders.

SUMMARY

In the soil fertility study, plant yields were greatest when all three (N, P and K) elements were applied. The greatest growth was observed when the equivalent of 132 or 176 kg N/ha, 66 kg P/ha, and 165 or 330 kg K/ha was applied. The combination of 88 kg N/ha, 66 kg P/ha and 330 kg K/ha also produced good growth. These rates are greater than the 55, 29 and 55 lb/acre of N, P and K, respectively, applied in a previous field study in which poor seedling establishment was noted

(Palazzo et al. 1978). While all three elements were required for optimum leaf growth, phosphorus was the only element to significantly increase root growth When applied alone, N was the only element to increase leaf growth. Plant leaf growth was closely correlated with root growth.

Applications of P and K fertilizers increased the content of these elements in soils. Fertilizer applications also increased the amount of soluble salt in soils but not enough to impair growth. Increases in the application rate of N decreased soil pH, which points up the importance of liming when large amounts of fertilizer are being applied.

Both N and P were required to promote yields at the lower application rates, while K was not an important factor for growth. The equivalent of 88 kg N/ha was required to obtain a significant increase in growth when only N was applied during this 133-day study. A similar yield was noted when the lower 44-kg-N/ha rate was applied in combination with 66 kg P/ha.

In the grass study, plant heights increased at each sampling date up to 56 days of growth. After this date, growth leveled off, probably due to a depletion of fertilizer. Greater differences in growth and nutrient utilization or color of plants showed after this time.

Among the types of grasses tested, the Kentucky bluegrass varieties were slow to establish. Reubens and common were the best performers among them, with Reubens producing the greatest yields. Although some fescues established slowly, they were all similar in vigor after 76 days. FL 1 hard fescue and Pennlawn red fescue were the greatest yielders. The tall fescues and ryegrasses established themselves more quickly than other species, and all produced high yields. K-31 and T-5 appeared to have slightly better soil-covering characteristics than the variety L-FA-Syn I. Annual ryegrass was the most vigorous species. Yorktown II also performed well. The wheatgrasses did well in the greenhouse, but since they are not normally grown in the northeast, this plant will have to be field-tested to determine its suitability.

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